

# SDHW Installation Basics Part 3: Drainback System

Chuck Marken & Ken Olson

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Chuck Marken installing a do-it-yourself SDHW system —  
a factory-made 12 gallon drainback tank with an internal heat exchanger next to an 80 gallon storage tank.

If you plan to produce solar heated water year-round in a climate that freezes, you need a solar hot water system with freeze protection. Drainback solar domestic hot water (SDHW) systems use the same types of collectors, circulating pumps, and controls as antifreeze systems. They are a bit less forgiving, but require fewer parts and are simpler to install.

The components and operation of drainback SDHW systems were covered in *HP87*. Nuts and bolts installation basics (collector mounting, controls, and soldering) were addressed in *HP94*. Reviewing these articles will give you a good understanding of the subject of this article—the installation of drainback SDHW systems.

## *Drainback, Not Draindown*

Drainback (DB) solar hot water systems should not be confused with the highly problematic draindown system. Draindown systems first appeared in the early 1980s. They circulated tap water through the collectors and relied on an electrically operated valve for freeze protection. Draindown valves were prone to failure for many reasons. We do *not* recommend draindown systems.

Drainback systems have a high degree of freeze protection, although they are not considered quite as fail-

safe as the antifreeze closed loop system described in *HP85* and *HP95*. A much simpler design than the closed loop antifreeze system, a drainback system provides good freeze protection in moderate to cold climates.

## *DB System Operation*

The major components of a DB system are the collectors, drainback tank (aka reservoir tank), hot water storage tank, heat exchanger, and one or two circulation pumps, depending on system configuration.

The drainback system is a closed loop system. However, unlike the closed loop antifreeze system, a DB system has an unpressurized closed loop, and it does not usually use antifreeze as the collector fluid. The collectors and drainback tank are part of a closed loop, which contains both air and the collector fluid, which is usually water. When the system is not operating, all the water is in the

drainback tank, located indoors or in another freeze-free environment. The collectors and outdoor piping have only air left in them. That is the freeze protection strategy.

When the system is activated, the collector loop circulation pump lifts the fluid up to the collectors. Once it passes through the collectors, it returns to the drainback tank by gravity. When the system is deactivated by the controller, the pump turns off and all the fluid in the collector drains back to the drainback tank. Drainback systems require a high head pump to lift the collector fluid the full height to the collectors.

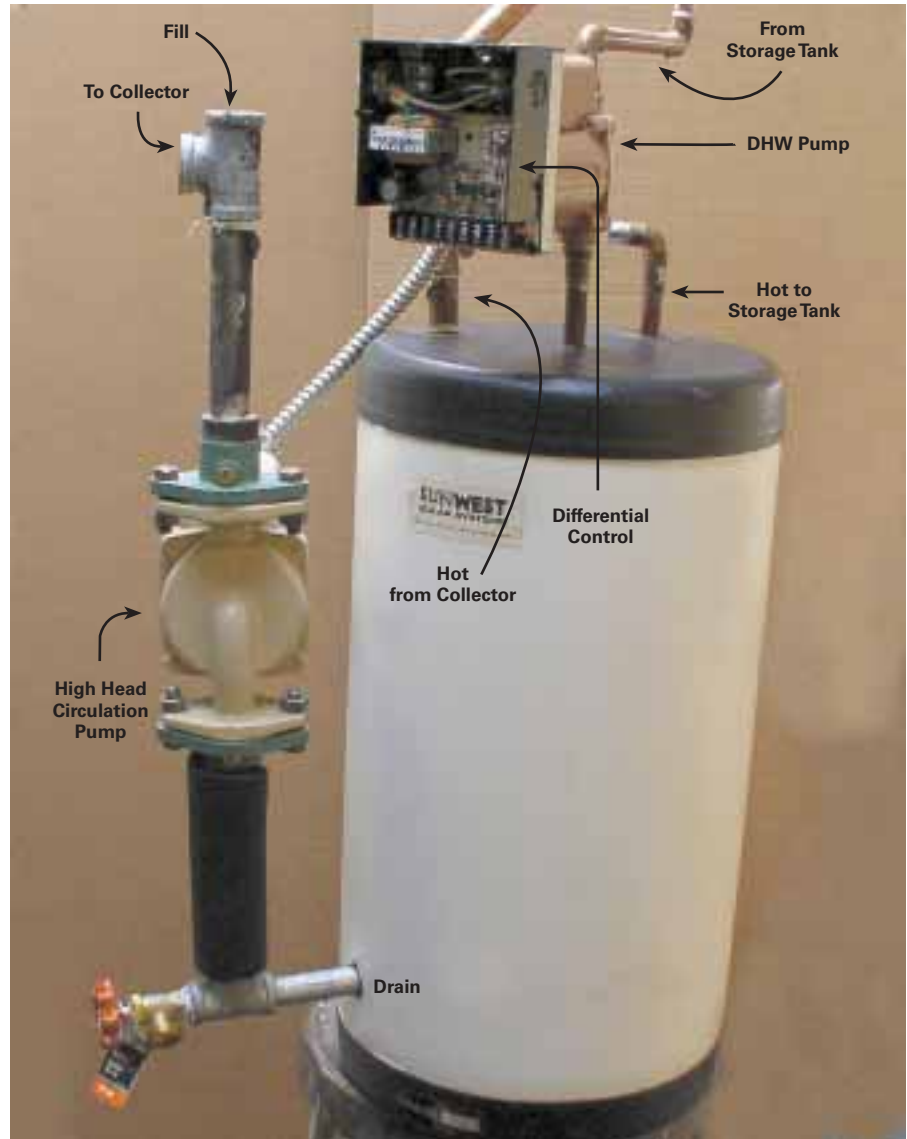
The solar heat removed from the collectors is transferred to the hot water storage tank by means of a heat exchanger. Several tank/heat exchanger configurations are discussed below. DB system design can be very simple. If the proper care is taken with collector mounting and piping, the rest is a breeze.

## Collector & Piping Installation

The collector mounting details described in the "Installation Basics" article in *HP94* must be modified slightly for drainback systems. The basics of securing, tilting, and orienting the collectors for all SDHW systems apply to drainback systems. However, drainback collectors must be installed so that they will completely drain when the pump shuts off.

This is accomplished by sloping the collectors toward the collector inlet. The slope should be a minimum of  $\frac{1}{8}$  inch (3 mm) per foot (30 cm) and preferably  $\frac{1}{4}$  inch or more (6 mm) per foot. For a 4 by 8 foot (1.2 m x 2.4 m) collector mounted with the long dimension vertical, this will be 1 inch (2.5 cm) per collector. This slight slope will normally not be noticeable to the eye unless many collectors are installed in a long row or near the roof edges. For large systems where the drainback slope may be visible and objectionable, collectors may be installed in multiple shorter rows.

Drainback systems should always be installed with the hot return pipe as vertical as possible. The collector loop piping in drainback systems should be a minimum of  $\frac{3}{4}$  inch. This minimum pipe size and steep slope allow for air in the drainback tank to quickly rise to the top of the collector and break the vacuum that would otherwise hold the water in the pipe. A well-known demonstration of this

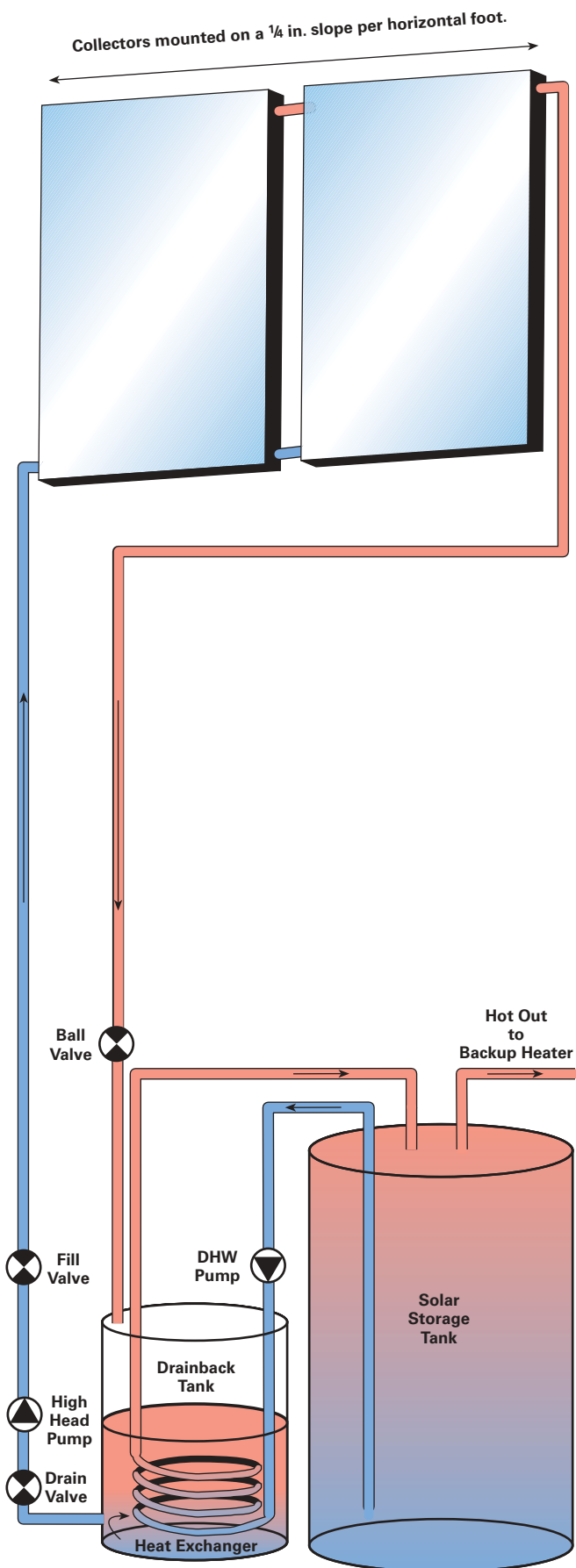


A factory-made, 12 gallon drainback tank.

vacuum phenomenon is holding your finger over the top of a common drinking straw filled with a liquid. The liquid remains in the straw until you remove your finger. Removing your finger breaks the vacuum by allowing air to enter the top of the straw, allowing the liquid to drain.

Collectors used in drainback systems should have riser tubes at least  $\frac{1}{2}$  inch in diameter. Most collectors are manufactured with the intention that these small riser tubes will be installed in a vertical orientation. In some collectors, the riser tubes have very little structural integrity when mounted horizontally. For example, mounting 4 by 8 foot collectors with the longer 8 foot dimension horizontal can pose a problem in DB systems. (It's not a problem in antifreeze closed loop systems.) The riser tubes can sag with gravity over time and cause a water trap in the tubing. The trap can hold water that would otherwise have drained out, causing a freeze break in the tubes.

## Drainback Design #1



## Drainback System Configurations

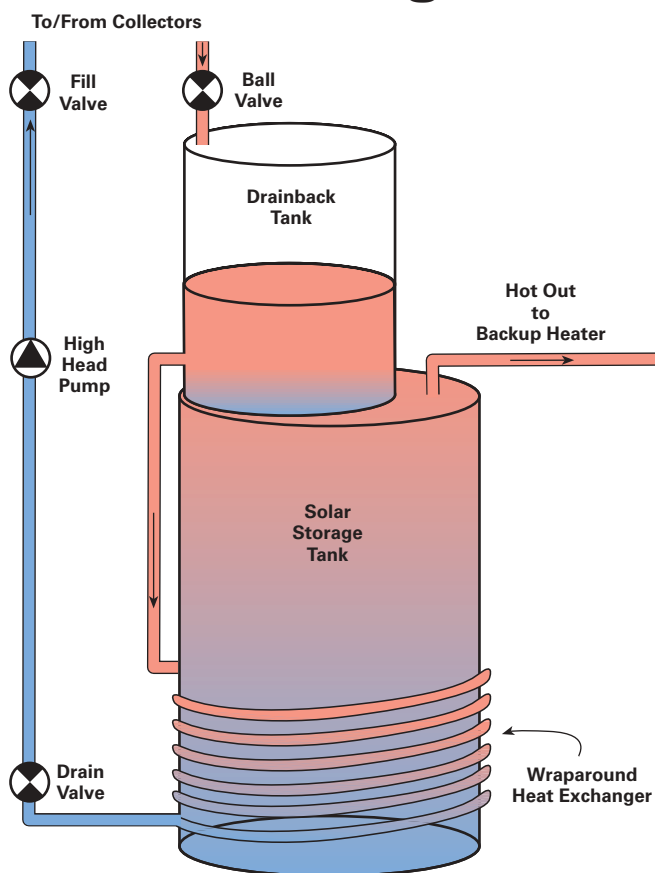
All DB systems have some type of unpressurized tank or reservoir to hold the collector fluid, which is usually water. Technically, the DB tank is unpressurized, although in some systems, pressure can build up with the rise in temperature of the collector loop and DB tank.

Drainback systems may have the heat exchanger integrated with the DB tank, integrated with the hot water storage tank, or external. One classic design (see DB Design #1) uses a DB tank with an integral heat exchanger. The water in the DB tank is circulated through the collectors, and the domestic hot water is circulated through the heat exchanger to a pressurized storage tank. The collector pump and the domestic water pump work simultaneously. The integrated heat exchanger is a coil of copper tubing inside the DB tank. The DB tank is usually filled with potable water, which makes a single-wall heat exchanger acceptable. (See *HP87* and *HP93*.) Systems using a toxic heat transfer fluid are required by most codes to use a double-wall heat exchanger.

DB system designs can also use a DB tank without a heat exchanger (see DB Design #2) if a storage tank with an integral heat exchanger is used. In this configuration, the collector fluid is circulated through both the heat exchanger and DB tank.

DB systems can also be designed with an external heat exchanger (see DB Design #3). This configuration uses two

## Drainback Design #2



circulation pumps. The collector loop pump circulates fluid through the collectors, heat exchanger, and DB tank. The domestic water pump circulates potable water from the hot water storage tank through the water side of the heat exchanger. If the collector fluid is not toxic, a single-wall heat exchanger may be used. A simple, low-cost homebrew heat exchanger is described in this issue (see "Homebrew Heat Exchanger").

Drainback tanks need to be large enough to be at least half full when the pumps are on; otherwise the heat exchanger will not be able to transfer heat to the domestic water. The total volume of the DB tank must be at least twice the volume required by the collectors and piping. A 4 by 8 foot collector will hold about a gallon (4 l) of water. In the collector loop, one hundred feet of  $\frac{3}{4}$  inch tubing will hold 2.3 gallons (9 l), or 4 gallons (15 l) for 1 inch tubing.

## Drainback Tank Designs

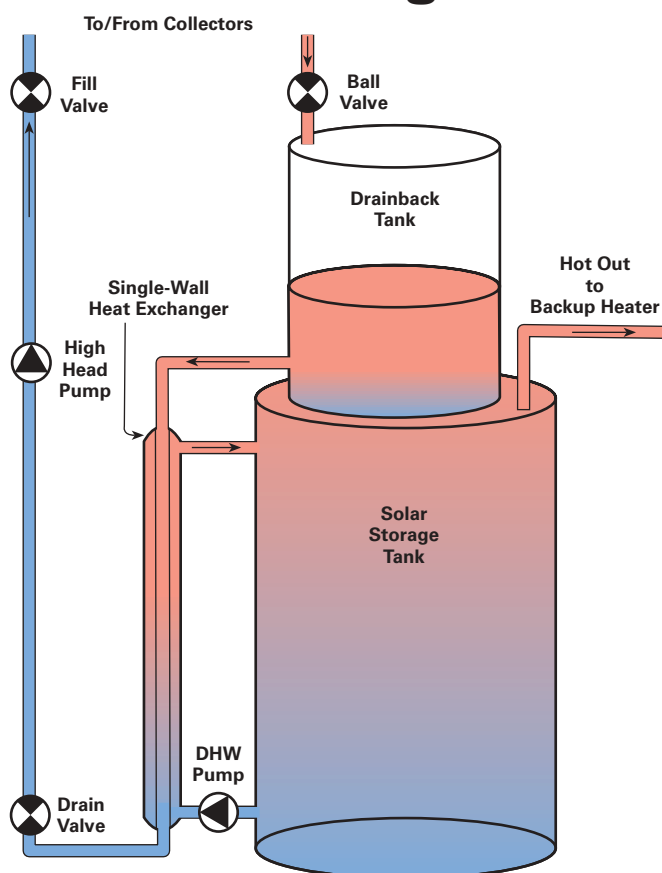
DB tank configurations can be classified into four popular designs. More designs are possible, but they will all be modifications of these four. The numbering order below does not reflect any recommendation of the merit of any of the designs. They may all be expected to have good overall system efficiencies. Your choice of design is more dependent on the amount of work you want to do and the availability and cost of the various types of tanks.

**Design #1.** Factory-made, 12 gallon (45 l), stainless steel tanks with single-wall heat exchanger are available from Radco, but they will cost in excess of US\$500. These tanks have a 30 foot (9 m) coil of  $\frac{1}{2}$  inch copper tubing as a built-in heat exchanger. They come fully insulated with an enameled steel outer covering. They look just like a small water heater except for the extra connections. With a tank like this, the installation is easy. Just install the pumps and control, connect the piping to the collector and storage tank, fill the tank with water, and the installation is complete.

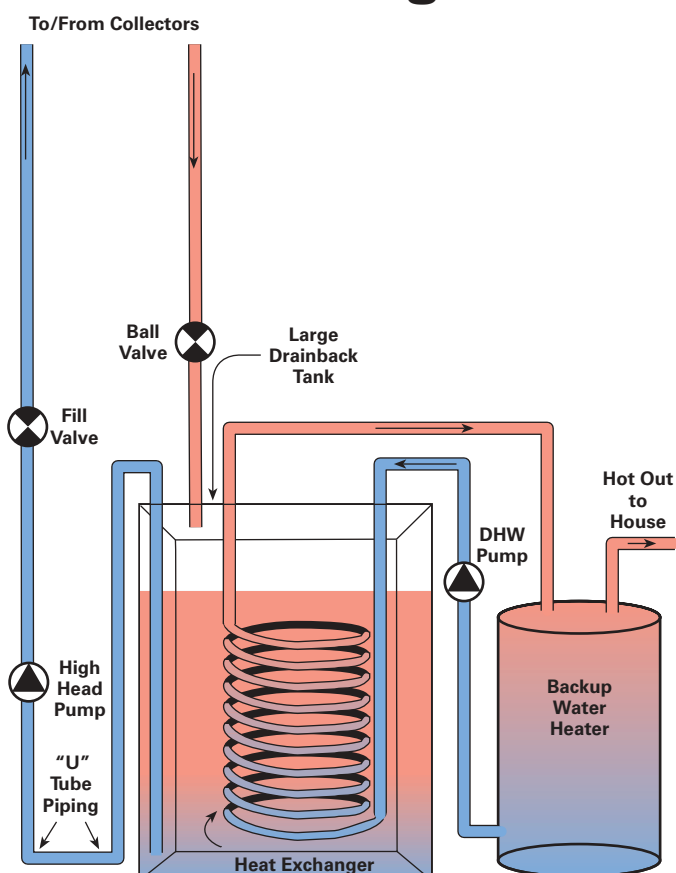
**Design #2.** Another design uses an immersed heat exchanger or a wraparound heat exchanger integrated with the hot water storage tank. This design requires only one pump in the system. The DB tank in this system can be a modified 10 or 20 gallon (38 or 76 l) electric water heater. The drainback tank may be mounted on top of the regular water heater or on an elevated shelf to lessen the head requirements of the pump. The collector loop water flows through the DB tank and the integrated storage tank exchanger, and is then pumped back to the collector using a high head pump.

**Design #3.** As with closed loop systems, you may also use an external heat exchanger. Although external heat exchangers are less efficient, you will have a wider choice of tanks. The DB and storage tanks may both be modified conventional water heaters. External, tube-in-tube single-wall heat exchangers can be readily made by a do-it-yourselfer. See "Homebrew Heat

### Drainback Design #3



### Drainback Design #4







**From the back of this drainback array of six, 4 by 8 foot collectors, the slight slope of the collectors can be seen.**

Exchanger” in this issue, and “Heat Exchangers” in *HP93*. The collector loop, water-flow path in this design is very similar to Design #2. This system requires a second pump to circulate domestic water through the heat exchanger. The DHW pump and collector loop pump are both turned on and off at the same time.

**Design #4.** Large solar thermal systems may use a large unpressurized storage tank as a DB tank. The first consideration should be material. Stainless steel, high temperature plastics, and fiberglass are all good choices for long life. If a tank, drum, or reservoir has a suitable large opening, or one can be easily cut, you can install a coil of copper tubing that will serve as the heat exchanger for the DHW. A second pump will circulate the domestic water through this coil to the hot water storage tank. The water in the DB tank will be circulated to the collectors. If the tank does not have a bottom fitting to connect to the collector loop pump, you can use the inverted “U” tube piping, as shown in the DB Design #4 diagram.

The pump control strategy in this system is different from the systems described above. There is often a demand for hot water when the sun isn’t shining. A separate differential control is used to turn the DHW pump on when cold water enters the backup water heater. This will allow the heat in the large DB tank to heat the DHW any time the DB storage tank has a sufficient temperature. These large combination drainback/storage tanks can also provide heat for other needs in a home. More coils in the tank can supply heat for home heating, hot tubs, or swimming pools.

Other tank designs have used a liner made of EPDM rubber or other similar material that will stand up under high temperatures. These tanks need an external support structure that can be made with angle iron and plywood. They are typically rectangular. The support structure is just a large box that the liner lies in. These tanks can be inexpensive for large DB systems, but the liners used in the past have a limited

lifetime—usually about ten years maximum. Leaks usually occur where the material has been folded.

## *High Head Pump Installation*

A high head pump is usually required in the collector loop of DB systems. How high depends on the installation. The pump must be capable of pumping the fluid from the DB tank to the top of the collector. As this pump pushes the liquid up through the piping system, the air is forced back down into the top of the DB tank. All DB systems will have a noticeable sound of gurgling upon startup, as the air and some liquid return to the DB tank. You should consider this when deciding whether to run the collector return pipe adjacent to a living space. The sound may be objectionable.

Small hot water circulating pumps that are suitable for DB collector loops have head limits of about 30 feet at sea level. Two pumps in wide use are the Taco 009 (maximum head 27 feet; 8.1 m), and the Grundfos 26-96 (maximum head, 31 feet; 9.3 m). The limit of readily available high head pumps is a consideration in design. Two-story homes with the DB tank in the basement can exceed these head limitations. Many pumps are available for higher head requirements, but you will pay a significant cost in the operation of the higher horsepower motors over the years.

Hot water circulating pumps must be placed below the water level of the DB tank. The pump impeller designs have no suction lift. That is a characteristic of most small centrifugal pumps. Suction lift pumps have impellers that will cause a vacuum on the input side of the pump and “suck” the liquid up the piping. Circulating pumps must be “wet” or primed at all times or they will not pump at all. This requirement may be a consideration in the type of DB tank you choose.

You can minimize the head in a DB system by elevating the DB tank. This can be accomplished by mounting the DB tank on a shelf or other suitable platform. Of course the DB tank must still be within a heated space or freeze-free environment.

## *Controls*

Drainback systems use a differential control as described in many previous articles and in depth in *HP94*. Since DB systems will always have a heat exchanger of some type, the differential temperature of the control should be similar to a closed loop system—on the order of 12 to 18°F (7–10°C) for the turn-on temperature difference and 4 to 8°F (2–4°C) for turn-off. A single control is all that is needed except for a system with a large, unpressurized combination drainback/storage tank.

## *Options*

If you have read the previous articles in this series (*HP94* and *HP95*), you can see that a drainback system has significantly fewer parts and complexity than a closed loop system. You may wish to consider installing a few other optional parts that are not strictly necessary, but can be helpful in monitoring the system operation.

Temperature gauges may be installed on the collector hot return piping, cold supply piping, and the hot pipe to the storage tank. A well-type temperature gauge is often used. It has two parts—the thermometer with a stem, and a fitting (well) that screws into the piping and accommodates the stem of the thermometer, making it possible to remove the thermometer or use it in numerous locations. These thermometers will give you a good idea of the system operation.

A sight gauge mounted on the drainback tank will let you know when you may need to add water to the tank. A transparent flow meter can be installed in the collector supply piping above the high head pump at the drainback tank water level to monitor the flow rate of the collector loop and also serve as a sight gauge.

A valve on the return line from the collectors will allow you to throttle down the return flow. Under some circumstances, fluid returning from the collector may fall faster than it is being pumped up to the collectors. This may cause it to be noisy. The valve will allow you to slow down the return flow to create a smoother, quieter, turbulent-free flow.

A simple system can also be configured using the drainback tank's immersed heat exchanger in series with the home's cold water supply to the water heater. This system was covered in *HP88* and *HP91*. This type of instantaneous design is dependent on the length and size of the tubing (many smaller tubes is better). Instantaneous designs are normally not satisfactory except in situations of very limited hot water usage.

## Filling & Startup

Demineralized or distilled water is best for drainback systems. Tap water may be used, but if the water is hard (with many dissolved solids) it can cause problems over time. The water in a drainback system does not fully drain. A thin film of water remains on the inner surface of the riser tubes each time it drains. Repeated evaporation of a film of hard water leaves a mineral deposit that can build up. This deposit acts as an insulator, which reduces thermal efficiency of heat transfer. Very hard water over many years can cause small riser tubes to become partially clogged and potentially retain a column of water. If this happens, the next freeze will likely burst that tube. You can minimize the possibility of this condition (aka capillary retention of water) by using collectors with riser tubes of the recommended minimum 1/2 inch diameter.

All of the drainback tank configurations should have a fill valve installed near or at the top of the tank. You can access the fill valve with a garden hose and washing machine hose to fill if you have tap water of acceptable quality. Or you may use a funnel if treated or distilled water is used. The tank should be filled to the top, but not above the fill valve. Once you have filled the system, turn it on and observe. When you are satisfied that you have no leaks and that the system is operating correctly, turn the controller to the automatic position and put your tools away.



Three, 3 by 8 foot collectors and piping, draining to the left.

## Drainback Drawbacks

Drainback systems are not considered as fail-safe as closed loop antifreeze systems. The main reason is the potential for failure to properly drain. Potential causes include the water quality issues discussed above, and malfunction of a sensor or control. These are rare circumstances but as we all know—life happens.

The possibilities include a control locked in the “on” position. This can be the result of a sensor malfunction or a sensor wire shorted or open. It can also be caused by the interior relay of the control freezing in the “on” position. If the control locks on, it will run the collector loop pump at night, and possibly in freezing weather. This can freeze the water in the collectors and cause the tubes to burst.

Another less likely failure mode may occur when you stack pumps in series to achieve higher head requirements. Pumps plumbed in series (outlet of one to inlet of the other) will double the head pressure. Pumps can be stacked in this manner for the head requirements in homes with two stories and the drainback tank in the basement. This can overcome the head limitations of a single pump. The problem with pumps in series occurs when one pump fails and the other continues to pump. The water will not rise to the top of the collectors any longer, but it will rise to the point of the head of the single pump. If the water level rises to an unheated attic or part way into the collector, you have a potential for freezing.

## Glycol Drainback

The problems discussed above can be addressed by modifying the drainback system to circulate a solution of water and propylene glycol. This concept moves us somewhat closer to the closed loop antifreeze system, but without the complexity of the pressurized loop. The glycol will afford a safety net level of freeze protection in the event of a system failure.

Even a 30 percent solution of propylene glycol in water will provide fail-safe freeze protection to -10°F (-23°C).

# hot water how-to

Glycol drainback system designs should incorporate the 325°F propylene glycol made by Dow Chemical. This higher temperature glycol mentioned in *HP89* will not break down the inhibitors in the solution below 325°F (163°C). But adding glycol necessitates the use of a double-wall heat exchanger to prevent mixing with domestic water.

## Maintenance

Check the water level in the drainback tank at least once a year. Fill it when needed. Drainback systems lose water over time—it evaporates. Even small drainback tanks in closed systems will lose water. If a DB tank loses enough water, the heat exchanger will no longer be immersed in the drainback tank. A dry heat exchanger transfers no heat. If the tank runs completely dry, the high head pump will likely burn up, since most of them are fluid lubricated.

The slope of the collectors and piping should be checked every year or two to ensure that they have proper drainage. Long runs of near horizontal piping are subject to sagging between supports. Even a small shifting of the collectors, however unlikely, can affect the system's ability to drain properly.

## Kick Back with Your Drainback System

We have covered the aspects of SDHW installation that are unique to drainback systems. If you live where it freezes, you need a reliable freeze protection design for your system. The drainback system is less costly and much simpler than the closed loop antifreeze design. If you follow the recommended practices, a drainback system will have reliable freeze resistance and generate hot water year-round, courtesy of the sun.

## Access

Chuck Marken, AAA Solar Supply Inc., 2021 Zearing NW, Albuquerque, NM 87104 • 800-245-0311 or 505-243-4900 • Fax: 505-243-0885 • [info@aaasolar.com](mailto:info@aaasolar.com) • [www.aaasolar.com](http://www.aaasolar.com)

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